Computer Graphics

- Display Technology -

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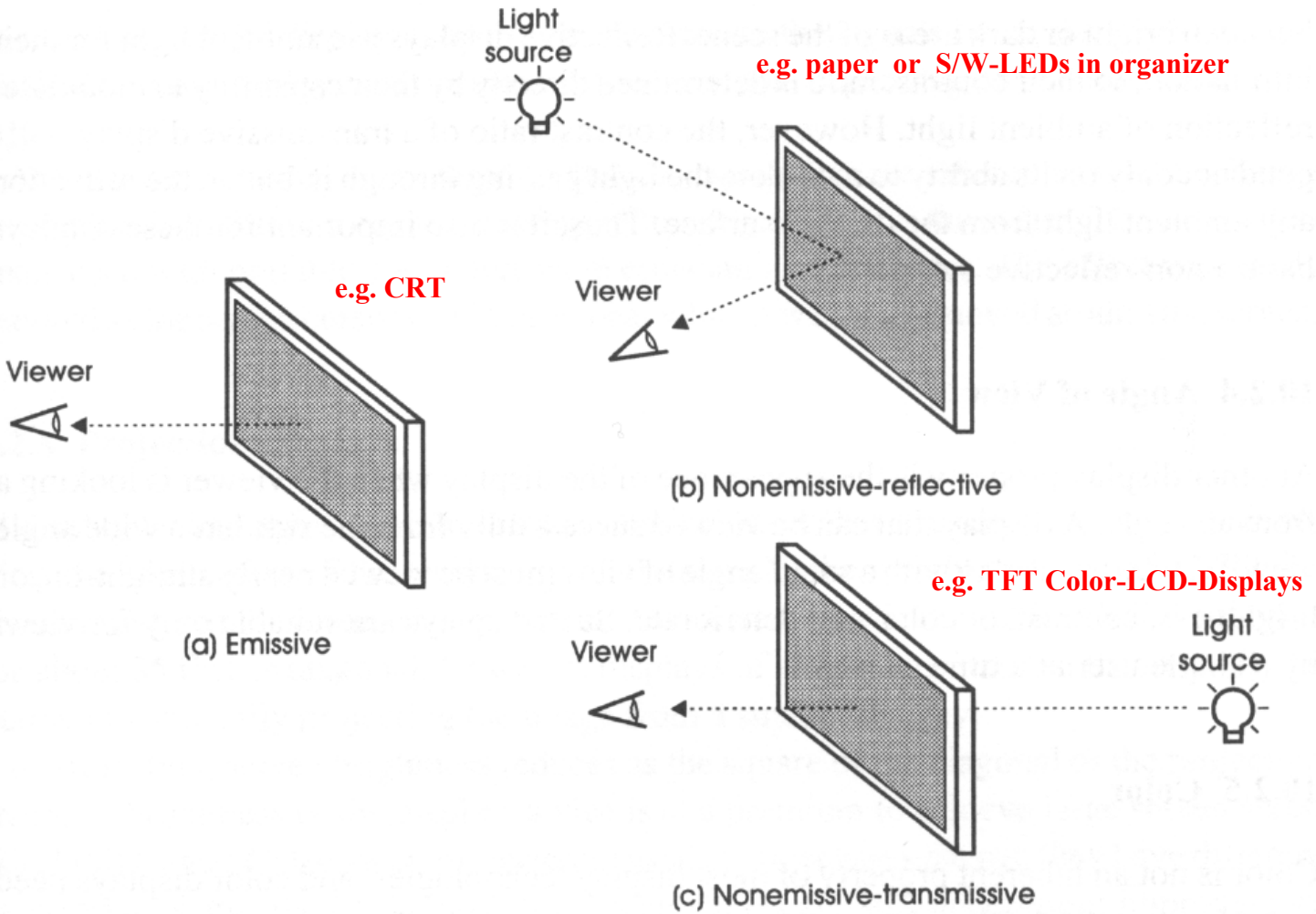
Overview

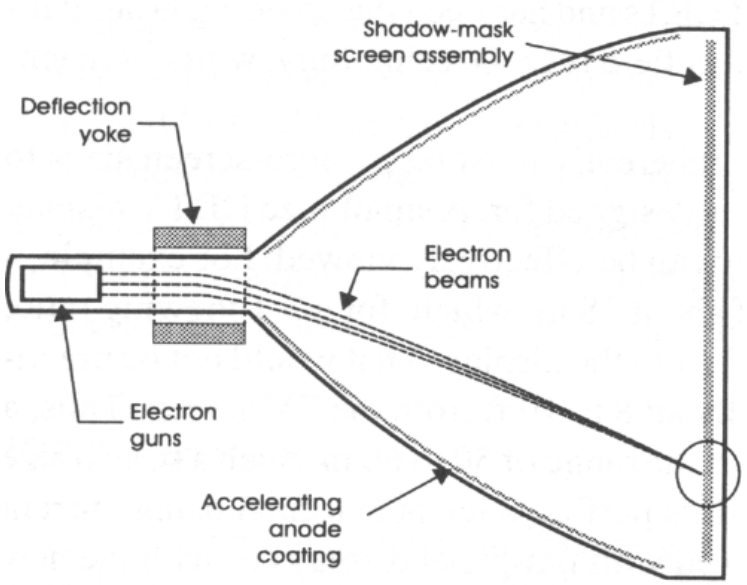
- **So far:**
  - ...
  - Signal processing
  - Antialiasing
- **Today:**
  - Display-Technology
    - Cathode-Ray-Display (CRT)
    - Liquid-Crystal-Display (LCD)
    - Plasma-Display-Panels (PDP)
    - Digital Micro-mirror Devices (DMD)
  - Resolution
  - Perception
- **Soon:**
  - Color
  - Animation

Display Technologies



Cathode Ray Display

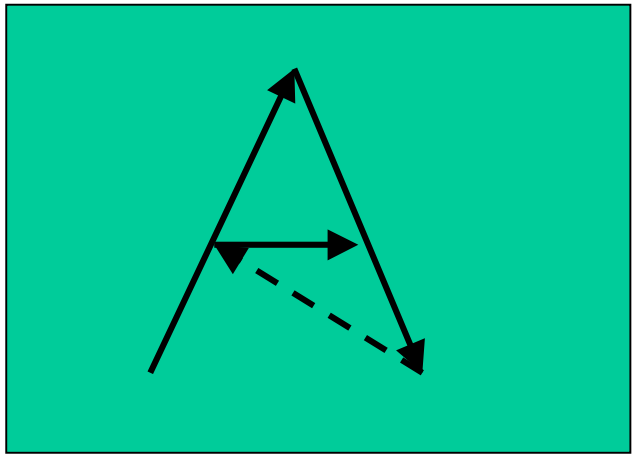
- **Braun's tube oscilloscope**
  - After luminescent layer
    - Fluorescence + Phosphorescence
    - But no phosphor:
      R: europium yttrium vanadate,
      G: zinc cadmium sulfide,
      B: zinc sulfide
  - Shelling with electrons
    - Electron gun
    - Steering grid (negative)
    - Focusing
    - Deflection
      - Electrostatic (fast changing, oscilloscope)
      - Electromagnetic (better focusing, graphics)
    - Acceleration (~20 KV)



Vector Display (´50s)

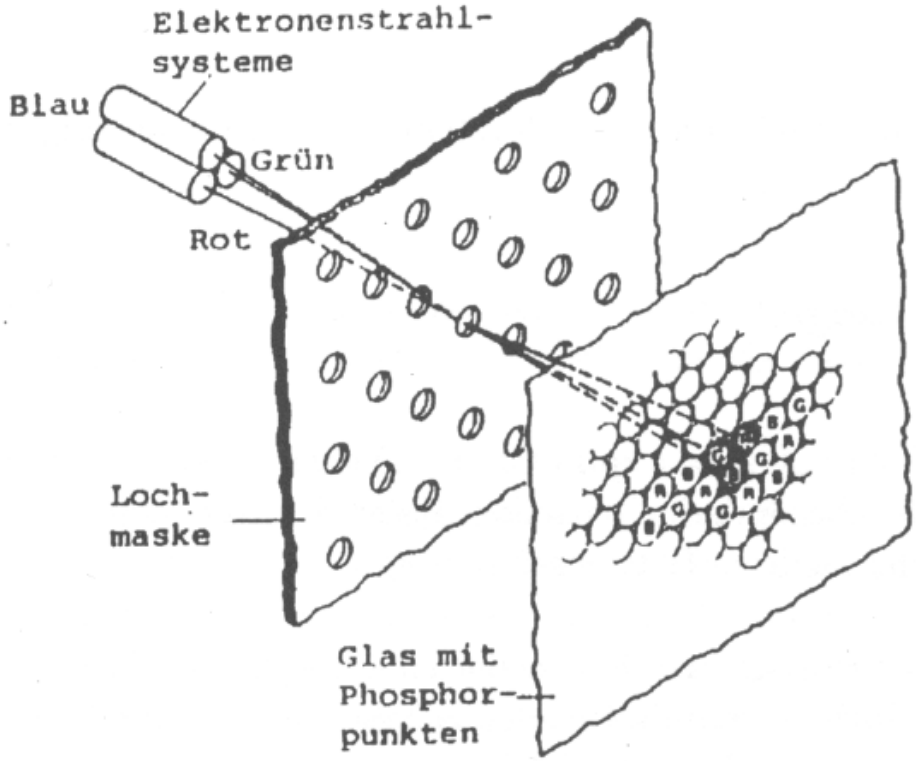
- **Simple oscilloscope**
  - Deflection in x & y
  - Direct controlling of the e-rays
- **Plus/Minus**
  - High resolution (4k x 4k)
  - Only vectors, no surfaces
  - Small complexity
  - Short after luminescent time

  ➔ Refreshing out off *display list*

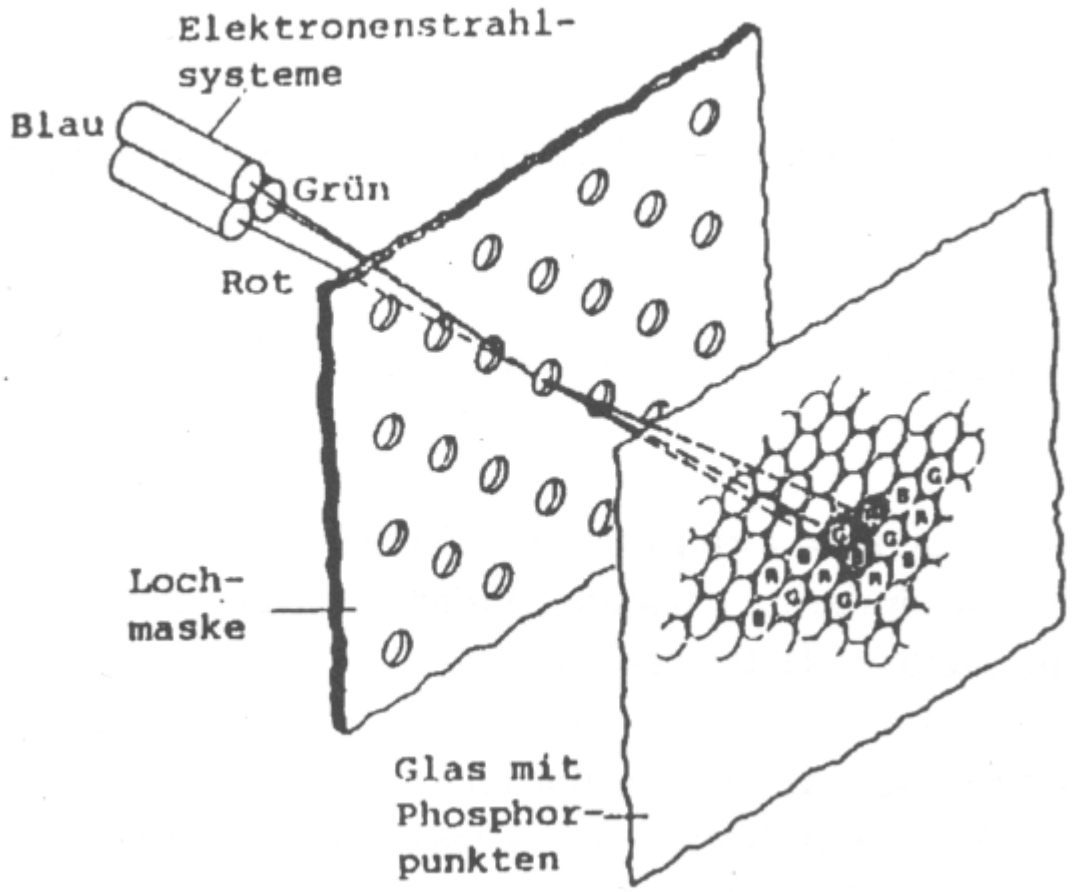


Shadow Mask

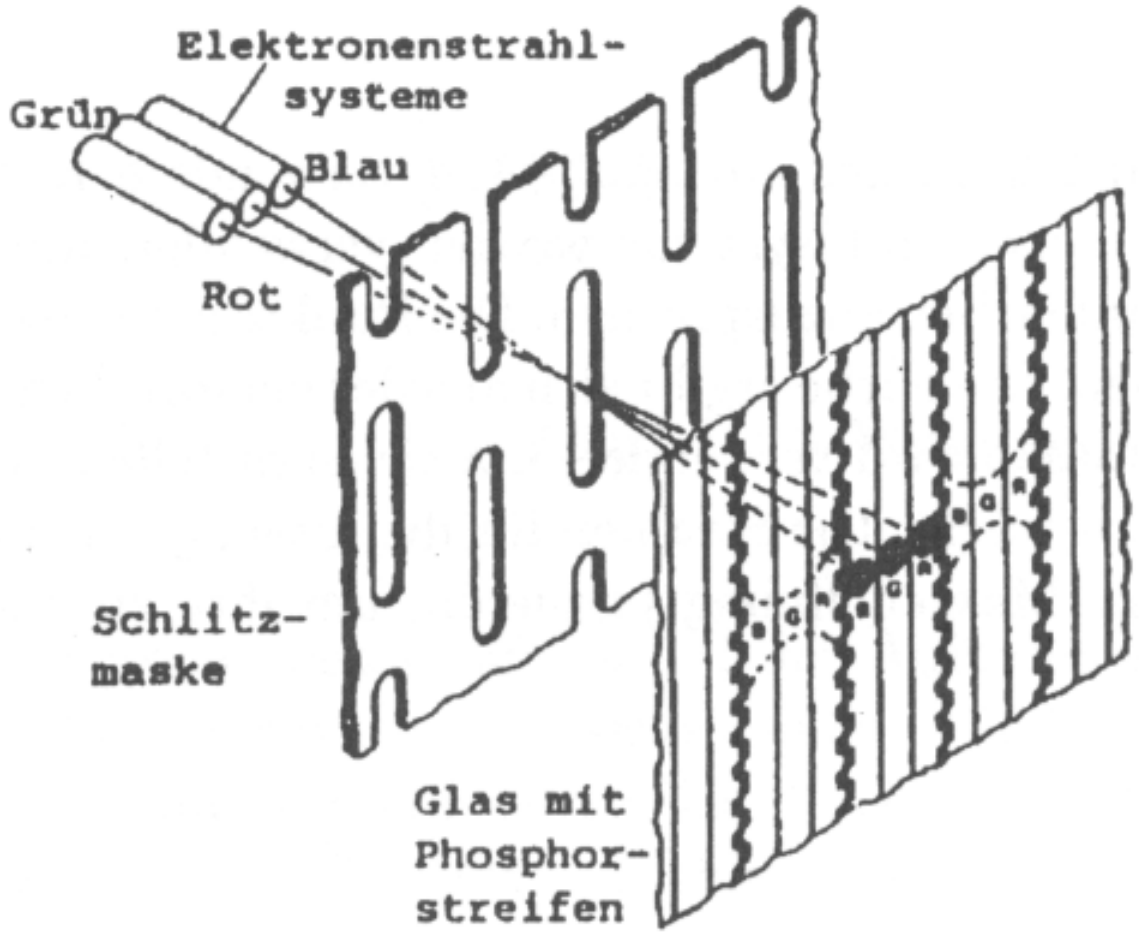
- **Color**
  - Several electron rays
  - Shadow mask
  - Mapping the mask onto the luminescent layer
  - Color grid at „phosphor“
  - Electron shadows
    - Gloomy image



Delta Shadow Mask



Inline Shadow Mask

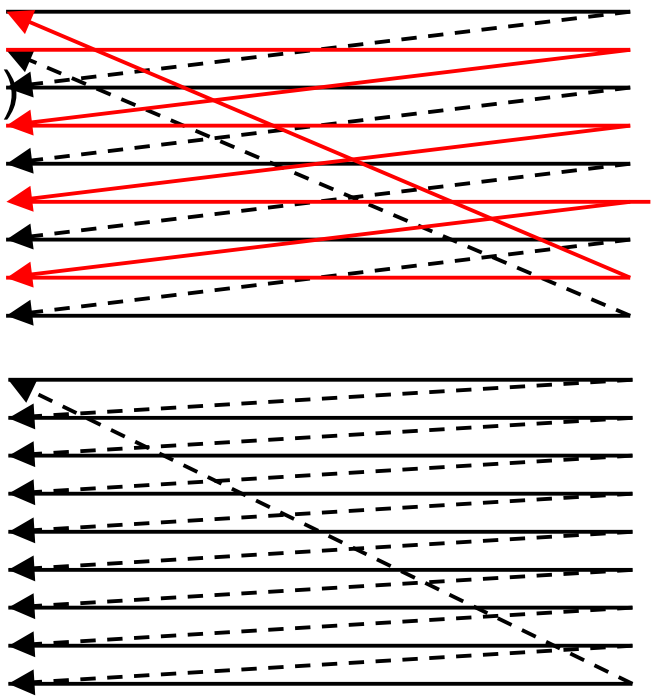


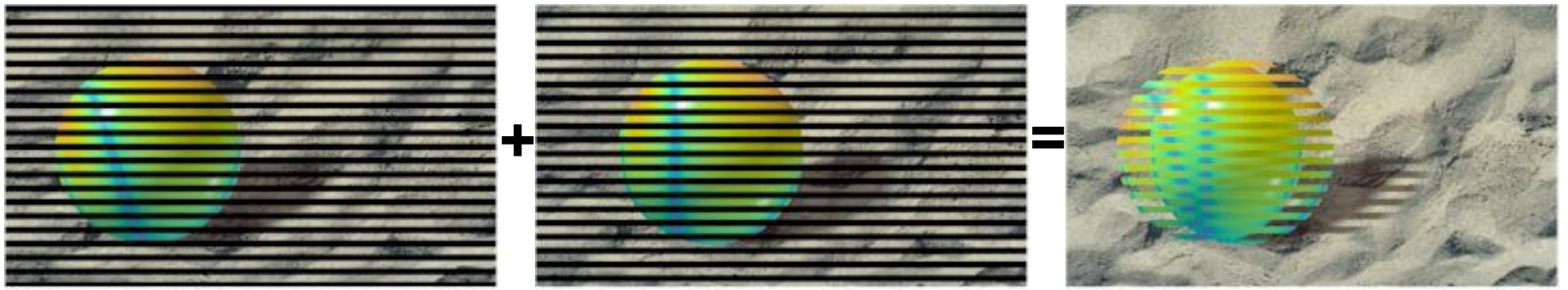
Trinitron Shadow Mask

- **Sony patent**
  - Instead of inline-mask fine metal strips (Aperture Grill™)
    - Brighter, because of fewer electron looses
    - Less glare - screen vertically flat (strips run straight from the top to the bottom)
  - Strips can tend to vibrate
    - Two horizontal wires
      - For stabilization
      - Slightly visible

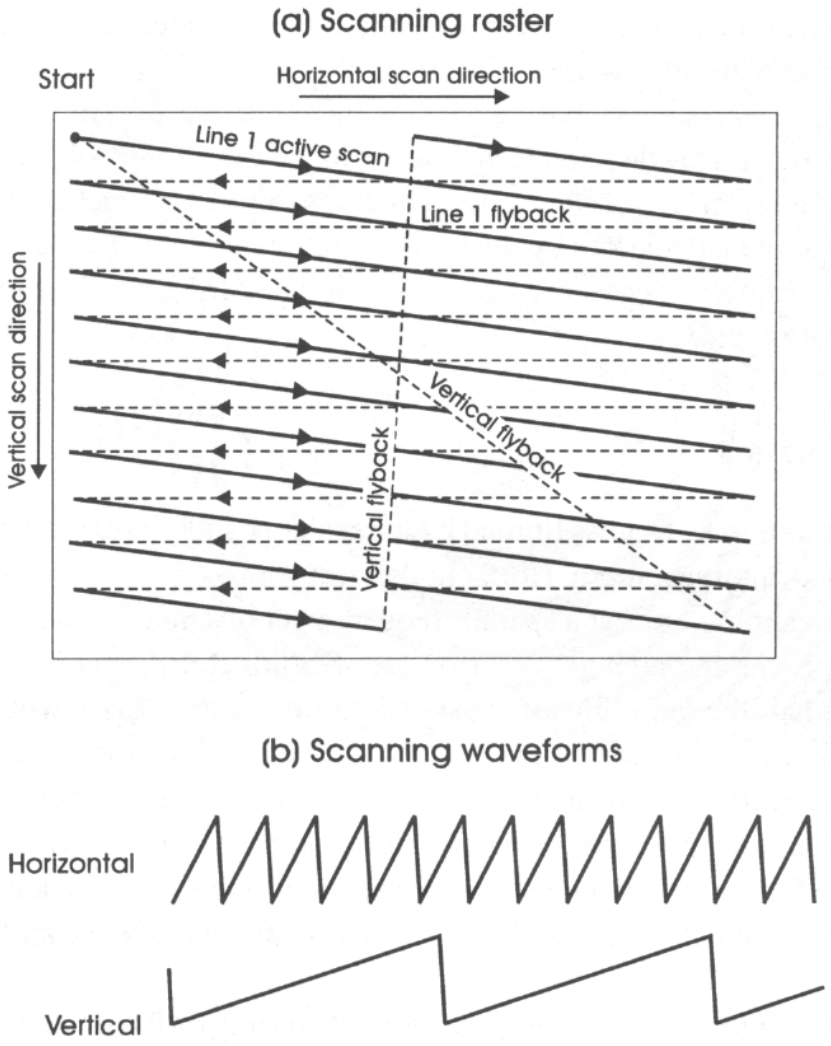
Scanning

- **Interlaced scanning**
  - 1 Frame (1/30s) = 2 Fields (each 1/60s)
  - Fewer data by the same refresh rate
  - Problem: Flickering, snaps
  - TVs working like this
- **Progressive scanning**
  - No snapping of the image
  - Simpler to calculate
  - Computers working like this



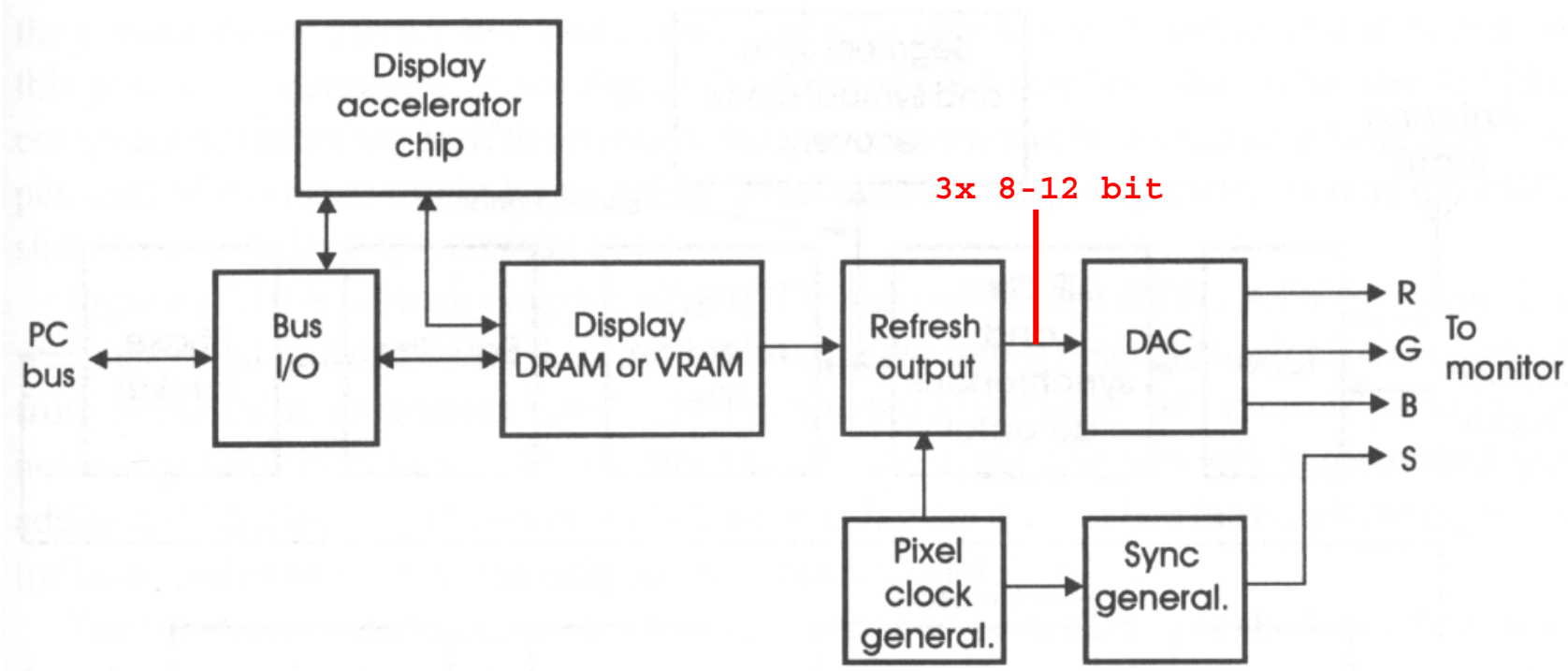


Interlaced Scanning



Scanning

- **Critical refresh rates for flickering**
  - Dark environment (cinema): ~50 Hz
  - Bright environment (office): 70-80 Hz
- **Controlling structure**



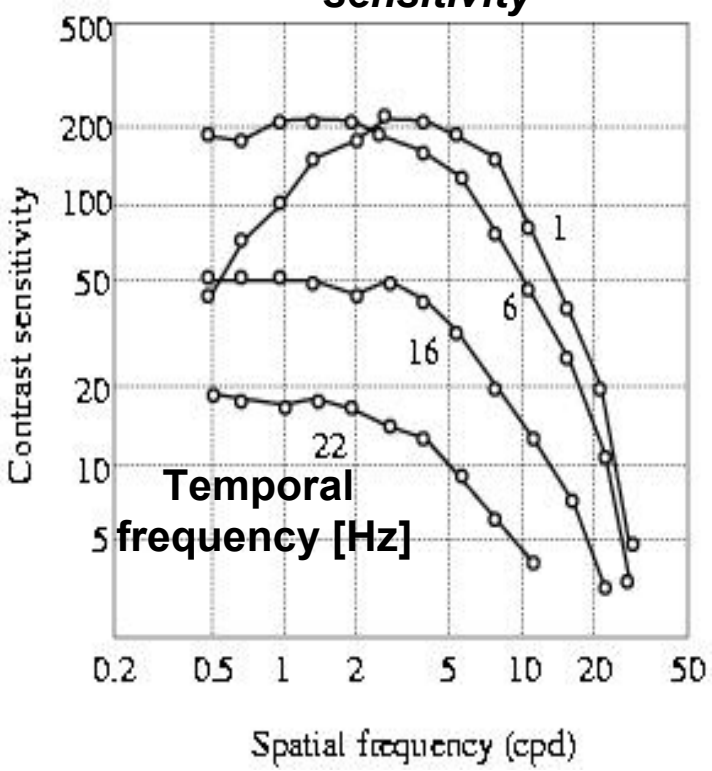
Problems

- **Depth**
  - Deflection may not be too large (i.e. 90 degrees)
- **Resolution**
  - Dot pitch, inline vs. delta
- **Brightness**
  - Shadowing effects through mask design
  - Bright ➔ many electrons ➔ rejection ➔ large dots
  - Saturation of the „phosphors“
- **Focusing**
  - Flat displays: dynamical past guidance

Problems

- **Reflecting light**
- **Flickering**
  - Increases with image intensity or ambient room lighting
  - Refresh rate versus phosphor's persistence
- **Magnetic fields**
  - Deflection interferences
  - Local variation of the color
- **High voltage**

Human Visual System sensitivity



LCDs

- **Utilizing of nematic molecules**
  - Elliptical shape
  - Rotating the polarization of the light at orientation across to the light
  - Aligning with
    - Splices at the surfaces
    - Alongside of a electromagnetic field
  - Combination with polarization filters
    - Light switch

LCDs

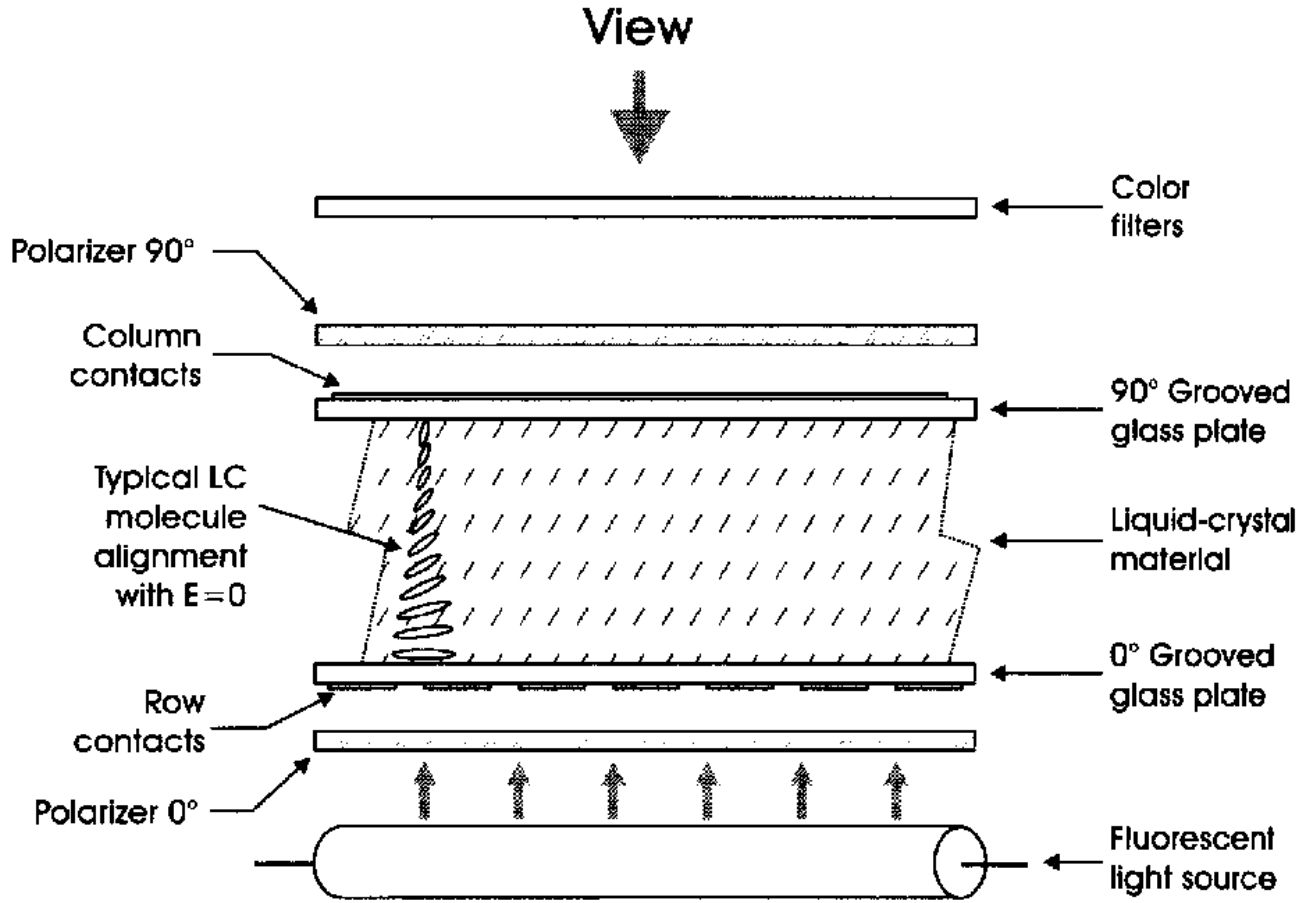
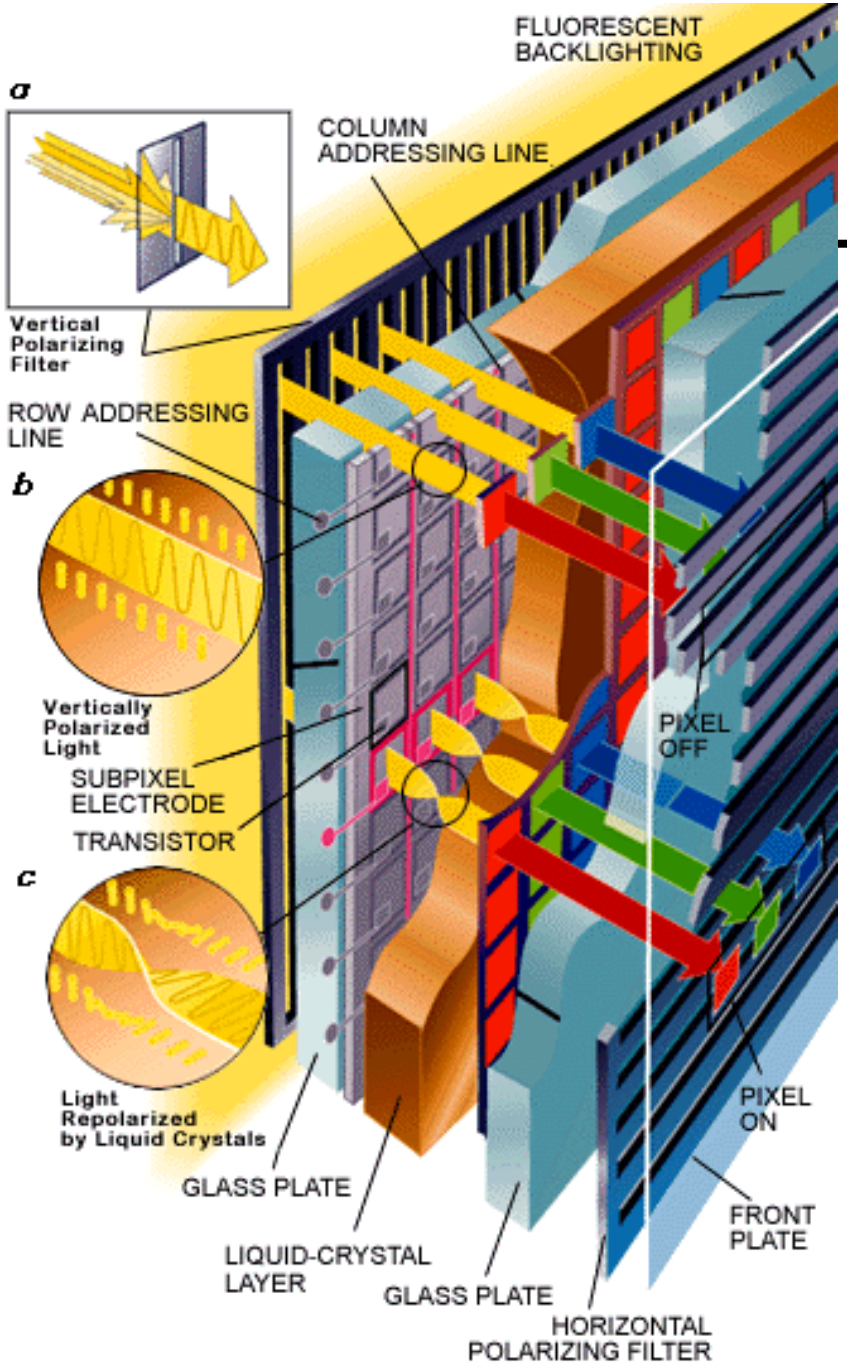


Figure 10.3 *Structure of an LCD panel. From A. F. Inglis, and A. C. Luther,* Video Engineering, Second Edition, *McGraw-Hill, New York, 1996, reproduced with permission of The McGraw-Hill Companies.*

LCDs


FLUORESCENT BACKLIGHTING
a
COLUMN ADDRESSING LINE
Vertical Polarizing Filter
ROW ADDRESSING LINE
b
Vertically Polarized Light
SUBPIXEL ELECTRODE
TRANSISTOR
c
Light Repolarized by Liquid Crystals
PIXEL OFF
PIXEL ON
GLASS PLATE
LIQUID-CRYSTAL LAYER
GLASS PLATE
FRONT PLATE
HORIZONTAL POLARIZING FILTER

Problems

- **Passive Matrix**
  - Refreshed periodically
  - After-images (crystal persistence)
- **Active Matrix**
  - One transistor per pixel
  - Brighter (light passes through continuously not only the during refresh cycle)
  - Still working too slow (~50 ms)
- **Color resolution**
  - Triple resolution in X (RGB)
  - Utilizing of anti-aliased fonts (clear type)
    - Displacement to the left at 1/3 pixel on RGB-pattern
    - One white pixel (rgbRGBrgb) ➔ blue + yellow (rgBRGbrgb)
  - Didn't work on CRT!
- **Illumination**
  - Transmission: Lamp (with optical fiber)
  - Reflection: Mirror behind LCD (no power)

Problems

- **Viewing angle**
  - Restricting, because of polarization
  - Color displacement
- **Production**
  - Pixel errors on large displays
  - Poor rate of yield (<50%)
  - Typical size up to 18“

Plasma Displays

- **Many small neon lamps**
  - Cells with xenon-gas
  - Gas discharge at high voltage
  - Plasma
    - cloud of electrons and positively charged xenon ions
  - UV-light stimulates „phosphor“
  - Orthogonal grid of electrodes to detonate
  - Large, bright displays
  - Complex and expensive

Plasma Displays

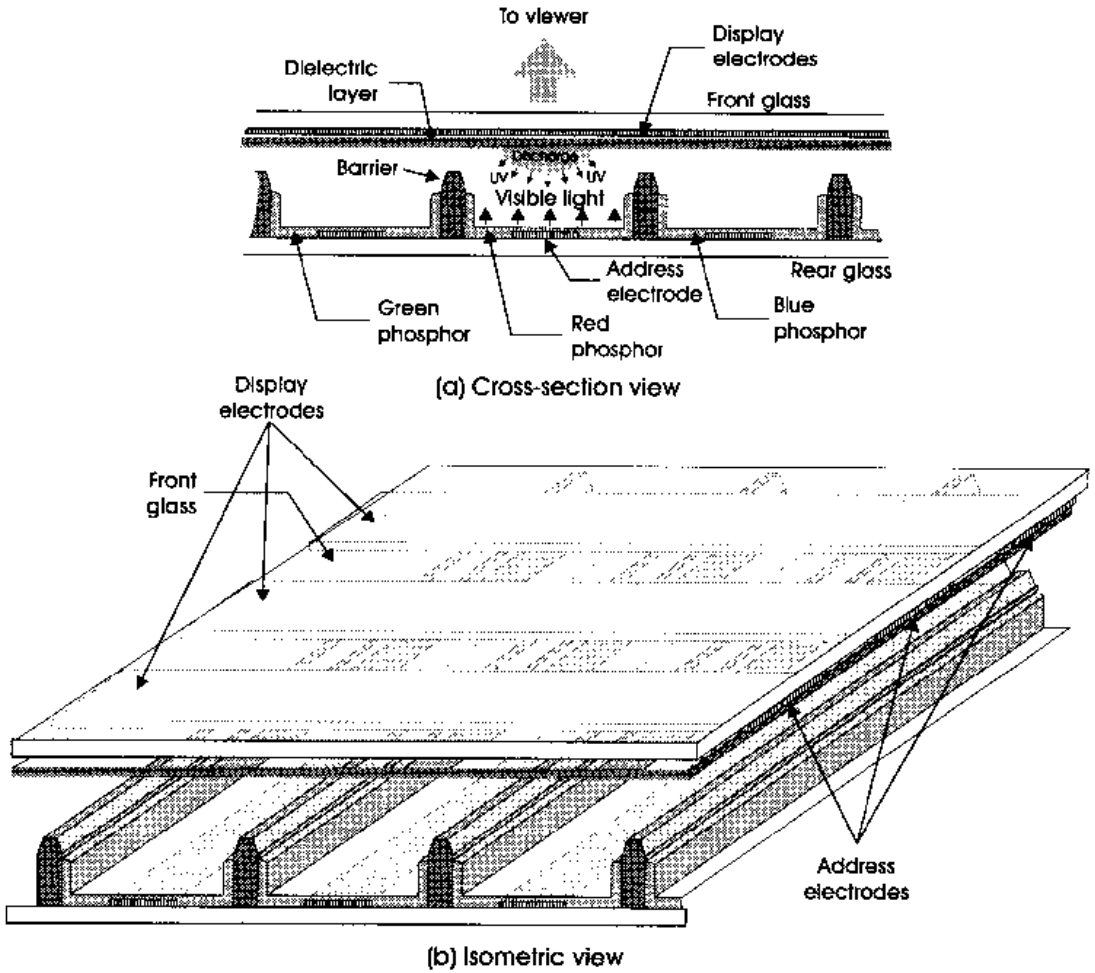


Figure 10.4 *Structure of a color plasma display panel (only the red cell is excited).*

Digital Micromirror Devices

- **Many small mirrors switching light**
  - 2D SRAM-cells
  - Followed by a layer of flexible micro-mirrors
  - Electrostatic deflection of the mirrors
    - ± 10 degrees
  - Gray values obtained through the duration of deflection
  - Color
    - Three DMDs
    - Time serial over color wheel
  - In fact
    - Fast switching (150 kHz), good contrast, bright
    - Very modern technology – at the experimentation stage

Digital Micromirror Displays

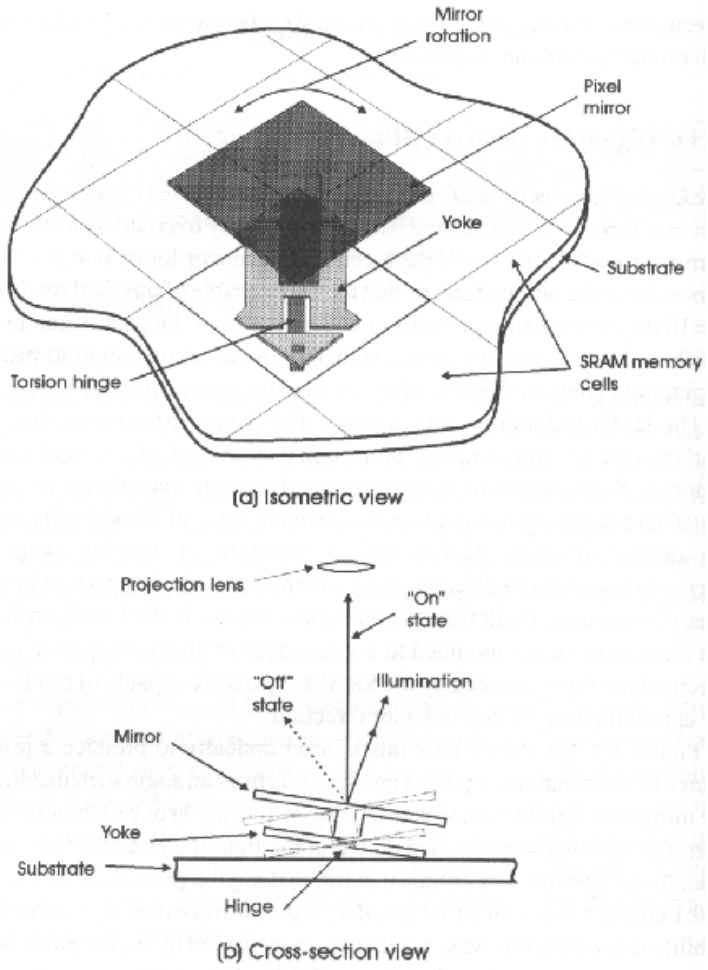


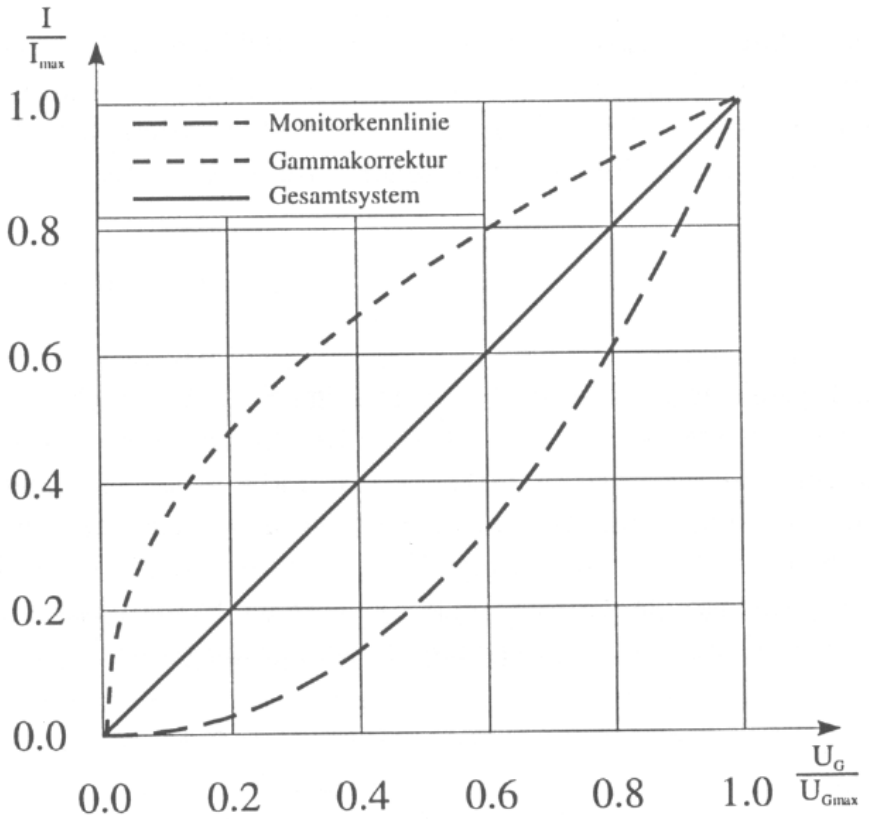
Figure 10.7 Diagram of one pixel of a DMD display.

Resolution

- **Color and intensity resolution**
- **Local resolution**
- **Time resolution**

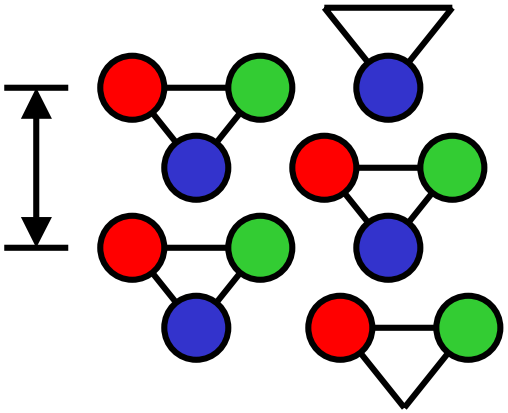
Intensity Resolution

- **Controlling the D/A-converter**
  - Bits per color channel
- **Display-gamma**
  - Characteristic of the electron sources
  - Gamma correction for linear transmission
  - Under 12 Bit loosing quality through quantization



Local Resolution

- **Dot-Pitch**
  - Distance between same colors
  - 19“-Monitor (Eizo):
    - 0.25 – 0.27 mm
  - Max. resolution
    - 39 x 29 cm: ~1600 x 1200
    - 15.5“ x 11.5“: 80-90 dots per inch (dpi)
    - Inline dot-pitch: 3 dots
    - Delta dot-pitch: 2 dots (better)
  - Controlling:
    - 1280 x 1024 recommended resolution

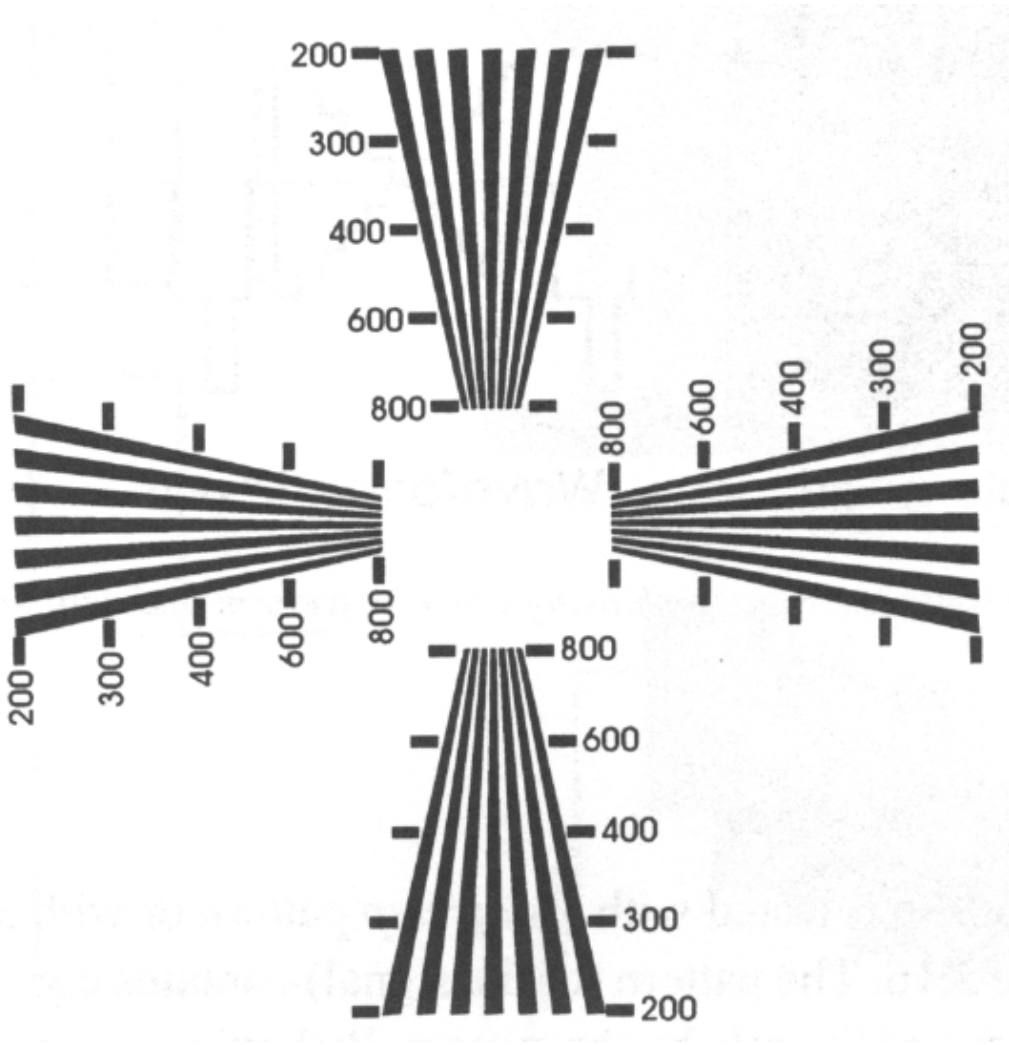


Physical Local Resolution

- **Measuring**
  - *line-pairs* per inch
    = lines per inch / 2
  - Ray patterns

- **Spot size**
  - Gaussian distribution of spot intensity
  - Spots perceived separately if
    - intensity at spot boundaries < 60% of the maximum
  - Brightness: blooming, clamping
  - Anisotropy
  - Different profiles of spots

Sample Pattern



Addressable Resolution

- **Measurement**
  - Pixel/inch (dpi) or number of pixels
- **Limited throughput**
  - D/A-converter, address range, frame buffer
- **Frame buffer**
  - Required scan-converting

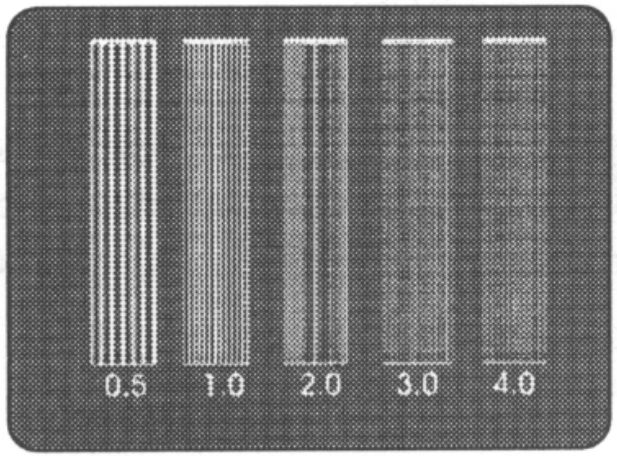
Typical Resolutions

- **TV:**
  - NTSC 640 x 480 x 8b 0.25 MB
  - HDTV 1920 x 1080 x 8b ~2 MB
- **Computer**
  - SVGA 800 x 600 x 8b ~1 MB
  - SXGA 1280 x 1024 x 24b ~4 MB
- **Laser printer**
  - A4 300 dpi x 8.5“ x 11.5“ x 1b ~1 MB
- **Movie**
  - 35 mm slide, 25 ASA (=125 l/mm),
    3000 x 2000 x 3 x 12b ~27 MB

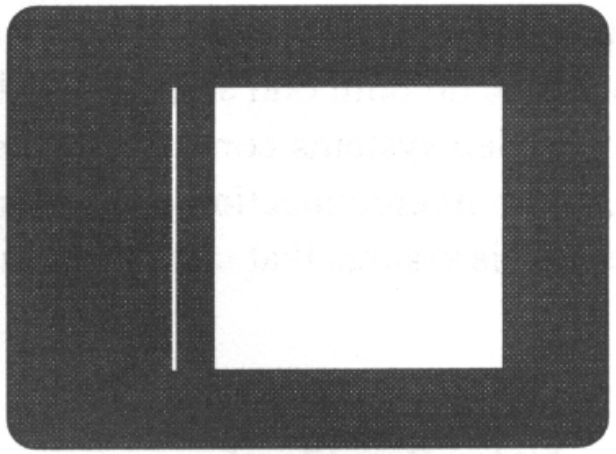
Time Resolution

- **Vertical / refresh rate**
  - Multi scan-monitor: 50-160 Hz (Eizo)
  - Movie: 48 Hz illumination, 24 Hz pictures
- **Horizontal / Line rate**
  - Monitor: 30 kHz – 96 kHz
- **Pixel rate**
  - Graphics cards: up to 350 MHz (GeForce)
  - Contrast reduction at high frequency
    - Frequency response of the monitor („Modulation transfer function“)
    - High frequencies more attenuated

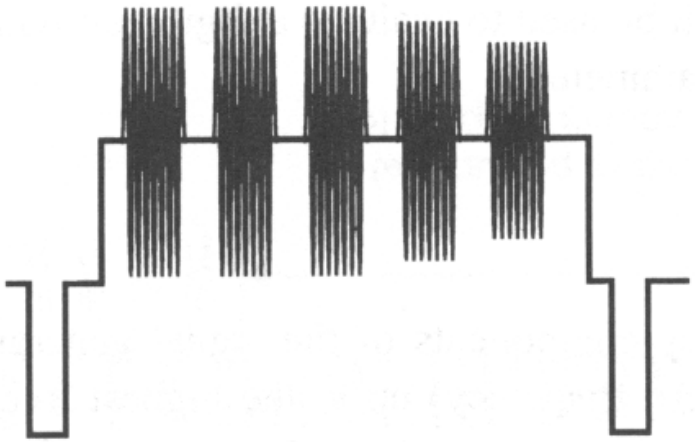
Frequency Response

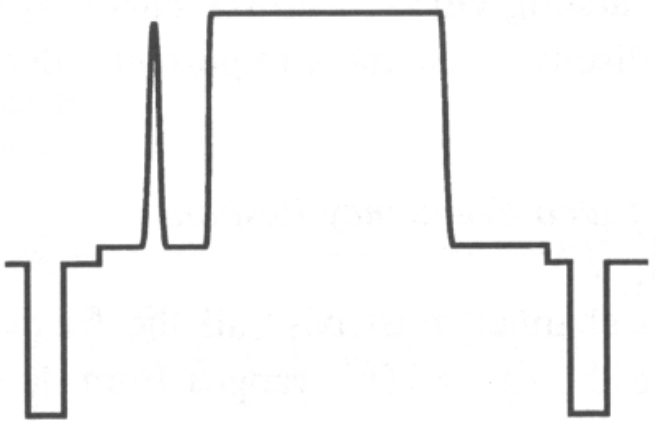


Multiburst



Pulse and bar





Aspect Ratio

- **Frame aspect ratio (FAR):**
  - TV: 4:3
  - HDTV: 16:9
  - Paper: ~3:4
  - Movie (35 mm): 3:2
  - Cinema (Panavision): 2.35:1 (display) anamorphic 2:1(movie)
- **Pixel aspect ratio (PAR):**
  - On graphics systems usually 1:1
  - Video not often!